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AUTHOR	Rogers, W. Todd; Hopkins, Kenneth D.
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ABSTRACT

Fourteen novel multiplication problems (of the form "a times b equals") were presented on each of five consecutive days to nine third grade classes divided into three groups. Immediate knowledge of results was provided for group one, delayed for group two, and no knowledge of results for group three. Residual scores, obtained by taking the difference between the number of novel problems answered correctly and the predicted number using stepwise multiple regression, were used as the dependent variables. These residual scores were analyzed using a four factor mixed model analyses of variance, with subjects nested within classes which in turn were nested within treatments. The fourth factor was a repeated measures factor (acquisition and retention tests for analyses one, treatment days for analysis two, and performance on non-novel problems for analysis three). No significant treatment effects were found. Significant differences among classes were observed, pointing out clearly how this source of variation, which has historically been implicitly pooled by investigators unfamiliar with statistical nesting, can affect scores. (Author/FL)

The Effect of Delay of Knowledge of Results on the Acquisition and Retention of Novel Multiplication Facts

W. Todd Rogers

Kenneth D. Hopkins

Laboratory of Educational Research

University of Colorado

Since the early fifties a number of experimental studies concerned with the effect of delay of knowledge of results on learning in human beings have appeared in the psychological literature. Prior to this time, delay of reinforcement had largely been confined to the study of lower animals, principally rats. The results of these rat studies suggested that delay of reinforcement impaired the acquisition of new learning, with no predictable outcome for the retention of the material learned (Renner, 1964). There is no such consensus in studies of human learning.

Several studies reported between 1955 and 1960 failed to find any deleterious effects of delayed knowledge of results on the speeds at which college students learned various simple motor tasks (Saltzman, Kanfer and Greenspoon, 1955; Bilodeau and Bilodeau, 1958; Mc Guigan,

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1959; Bilodeau and Ryan, 1960; Denny, Allard, Hall and Rokeach, 1960). The typical range of delay used in these studies was from 0 to 30 seconds. Bilodeau and Bilodeau (1958) and Denny et al (1960) have concluded, as a result of their findings, that the interaction between the intertrial interval and the post-knowledge of results interval was a more important variable than the delay interval.

In the experiments where a concept identification task or memory was involved, the results are contradictory. Saltzman (1951) investigated the effect of delaying knowledge of results on the rate of learning a list of four place numerals presented in a verbal maze. Using college students, he found that immediate reinforcement led to a higher rate of learning than a delay of six seconds. Sax (1960) found that an increased delay in knowledge of results (no delay, 10 minutes, 20 minutes, and 40 minutes) led to a significant increase in the number of trials needed by high school students to learn a series of Chinese symbols by the paired-associate method. Similarly, Bourne (1957) reported that the performance of students of an elementary psychology class, presented with the task of identifying a series of geometric patterns, was inversely related to the delay of feedback (0 to 8 seconds). However, in a later study (Bourne and Bunderson, 1963), in which the post-delay interval was kept constant, findings similar to those reported in the simple motor learning experiments were obtained.

Two studies by Brackbill and her collaborators (Brackbill and Kappy, 1962a; Brackbill, Issacs and Smelkinson, 1962b) failed to show that acquisition of a set of two choice discriminations by third grade boys was impaired by delay of reinforcement (0, 5, and 10 seconds). Markowitz and Renner (1966) proposed that the effect reported by Brackbill was due to feedback which was given in addition to the reinforcement. To verify their proposal, they replicated the discrimination procedures used by Brackbill, providing different combinations of feedback and immediate or delayed reinforcement. They found that when feedback is eliminated and reinforcement delayed, the number of trials to criterion increased significantly.

The studies of Sax, Brackbill, Issacs, and Smelkinson, and Markowitz and Renner investigated the effect of delaying knowledge of results on retention. As for acquisition, the results obtained were contradictory. Sax (1960) concluded that deley of knowledge of results (0 seconds, 10 minutes, 20 minutes, and 40 minutes) during acquisition was ineffective when retention (two week retention interval) was employed as the dependent variable. Brackbill and others (1962a, 1962b) found that delaying knowledge of results by 10 seconds during acquisition facilitated retention over the short interval (one day), but that this effect faded over the longer interval (eight days). Markowitz and Renner (1966) reported that retention by subjects given delayed feedback was significantly greater than by subjects having no feedback. For subjects having reinforcement, immediate or delayed, differences in retention were not significant. Markowitz and Renner concluded that the delayed retention effect reported by Brackbill was a function of the feedback present in her studies.

It is apparent that present knowledge regarding the effect of delay of knowledge of results on human learning is inconclusive.

Most studies have involved experimental controls, with an experimenter working individually with each subject. As a result, the external validity of the research findings to the classroom is uncertain. The aim of this study is to determine the effect of delay of knowledge of results on the learning of novel mathematical facts through drill in a classroom situation. Specifically, are there significant differences in the acquisition and retention of novel multiplication facts between groups of third-grade students provided with immediate knowledge of results, delayed knowledge of results, and no knowledge of results?

Method

Subjects

Nine classes of heterogeneously grouped third-grade pupils from five elementary schools were used in this study. The schools, located in a large metropolitan area, were selected on the basis of their size (each school except one contained two third-grade classes) and their proximity to each other.

Two factors were involved in choosing third-grade students as the population from which the experimental groups could be drawn. First, pupils of this grade were comparable to subjects used in previous psychological studies, notably those conducted by Brackbill and her collaborators, and by Markowitz and Renner. Second, suitable educational material which the students had not been exposed to and yet for which the basic groundwork had been laid could be found. In particular, multiplication of the natural numbers begins in the third grade, with those multiplication facts having products of 36 or less being developed as the year progresses.

Altogether 219 students of mean age 107.7 months and mean I.Q. of 107.2 (California Short-Form Test of Mental Maturity, Form 1H) were present for the entire experiment. None of these students possessed a hearing or speech disability.

The classes were assigned to the three treatments using a stratified ordering procedure. To partially balance school variance, no treatment was replicated in the same school. In addition, the treatments were distributed, so far as was possible, evenly throughout the day. An equal number of pupils per class (n = 15) was randomly selected from each of the nine classes. The assignment of treatments to classes is summarized in Table 1.

Materials

Multiplication test. The multiplication test involved a reading of all the problems of the form "a x b", "a" and "b" natural numbers between 1 and 10. The problems were arranged in a random order, each separated from the next by a response interval of three seconds. The oral presentation of a problem consisted of the number of the problem followed by the problem. For example, the test began: "Number 1: 3 times 3 equals (3 sec.). Number 2: 5 times 7 equals (3 sec.)." Each student was provided with an answer sheet on which he could record his answers. Since the test was to be administered on three different occasions to each of the nine classes, the possibility arose of variations in scores due to changes in delivery (for example, voice inflexion) and timing. To avoid this source of variance, a tape

Table 1

Assignment of Treatments to Classes

Class	School	Time	Treatment
1	A	9:05--9:25	Immediate Knowledge of Results
2	A	9:30--9:50	Delayed Knowledge of Results
3	B	10:00-10:20	No Knowledge of Results
4	C	11:00-11:20	Immediate Knowledge of Results
5	C	11:30-11:50	Delayed Knowledge of Results
6	D	1:05--1:25	Delayed Knowledge of Results
7	D	1:30--1:50	No Knowledge of Results
8	E	2:00--2:20	No Knowledge of Results
9	E	2:30--2:50	Immediate Knowledge of Results

recording of the test was used.

Novel multiplication facts. All of the students of each class were pretested using the multiplication test to ascertain their knowledge of the multiplication facts. Those problems which had a difficulty index of .05 or less were considered to be the novel problems. Fourteen such problems were found.

The fourteen novel problems were presented twice on each of five consecutive days. To avoid the possibility of serial learning, the problems were presented in a different random order on each day. The fourteen problems together with their difficulty indices (p) and daily orders of presentation are presented in Table 2.

The problems, each separated from the next by the response interval, were presented orally by the experimenter. For the classes provided with immediate knowledge of results, the presentation consisted of the number of each problem, the problem, a response interval, and the corresponding multiplication fact. For example, "Number 1: 6 times 7 equals (3 sec.). 6 times 7 equals 42. Number 2: 6 times 8 equals (3 sec.). 6 times 8 equals 48, etc." For the classes provided with delayed knowledge of results, the oral presentation consisted of the number of each problem, followed by the problem and response interval. Upon completion of both trials, the multiplication facts together with the corresponding number were read. For the classes provided with no knowledge of results, the oral presentation consisted of the number of each problem, followed by the problem and response interval.

Since each presentation was to be made to three classes, the

Table 2

The Novel Multiplication Facts: Difficulty Indices

and Daily Orders of Presentation

Fact	Dif'lt Index (p)	Order of Presentation									
		Day 3		Day 4		Day 5		Day 6		Day 7	
		Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
6x7	.043	1	10	3	11	5	8	12	9	11	8
6x8	.036	2	5	5	12	1	14	8	5	2	5
6x9	.018	3	3	8	13	2	1	9	11	12	13
7x6	.039	4	12	2	1	13	11	6	8	8	6
7x7	.043	5	13	11	3	12	5	5	6	13	7
7x8	.029	6	6	10	6	7	13	4	14	4	12
7x9	.014	7	2	7	9	4	6	7	1	9	3
8x6	.039	8	8	4	8	3	9	10	12	3	1
8x7	.025	9	1	14	14	14	7	3	2	6	14
8x8	.043	10	14	12	5	6	10	11	10	1	2
8x9	.021	11	4	9	4	11	3	2	7	14	4
9x6	.025	12	7	1	2	10	2	13	3	5	9
9x7	.007	13	9	13	7	8	12	14	4	7	11
9x8	.025	14	11	6	10	9	4	1	13	10	10

possibility arose of within-treatment variations due to changes in delivery and timing. To avoid this source of variance three tapes were used each day corresponding to the treatments and orders of presentation of the problems.

Procedure

On Day 1, the orientation day, the experimenter explained to the students of each class that they would be taking part in an experiment to determine how pupils of the third grade learn arithmetic. A trial run, using ten addition facts, was conducted to acquaint the students with the materials and procedures to be followed.

The pupils were pretested using the multiplication test on the second day to determine (a) their knowledge of the multiplication facts and (b) the novel multiplication facts. Before beginning the test, the students were told it was a test of multiplication and that some of the questions would be easy, while others would be quite difficult.

Day 3, the first of five consecutive treatment days, began with each student being provided with a study sheet of the fourteen novel facts to be learned. The facts were read aloud in the order in which they appeared on the study sheet. The students were then instructed to study the facts for a quiz to be given five minutes later. After the study period, the study sheets were collected and kept by the experimenter. Each class then received the appropriate tape for Day 3, the students recording their responses on the answer sheets provided. Both groups provided with knowledge of results were encouraged to mark their own papers, placing a "tick" beside an answer that was correct and a "cross" beside an incorrect answer or a space left blank. Students who were observed filling in the blanks during the reading of the answers were eliminated from the statistical analyses. Upon completion of each tape, the answer sheets were collected and kept by the experimenter.

The treatments were repeated on Days 4 through 7. After the tape on the seventh day, the multiplication test was re-administered to obtain a measure of acquisition. Six calendar days later the classes were retested using the multiplication test to obtain a measure of retention. During the retention interval, no instruction in multiplication facts, novel or non-novel, was given. The students were told, beofre taking the test, the the purpose of the test was to see how much they could remember from the previous week's work.

Analysis

Data

I.Q. scores and ages in months as of June 1 were collected from the permanent record cards of each student who participated in the experiment. From the three administrations of the multiplication test (pretest, acquisition test, and retention test) six different scores, corresponding to the number of novel problems answered correctly on each administration and to the number of non-novel problems answered correctly on each administration, were obtained for each student. In addition, five scores were obtained corresponding to the number of problems answered correctly on each of the treatment days. On each treatment day, a problem was marked correct only if the student provided the proper answer on both presentations.

Acquisition and Retention

Acquisition was defined as the difference between the number of novel problems answered correctly on the second administration of the multiplication test and the number predicted using stepwise multiple regression, employing I.Q., age, and total pretest score (total number of novel and non-novel problems answered correctly on the first administration of the problems) as predictors. To assess differential retention, the difference between the score for the third administration of the multiplication test and the predicted score (using the three predictors indicated above) was used. For both acquisition and retention the stepwise regression selected the pretest score as the best predictor with the remaining two predictors accounting for less than one additional percent of the variance. Because little was to be gained from the inclusion of all three predictors, only the pretest score was used for the analyses.

A four factor mixed model analysis of variance was employed in which 15 subjects were nested within each of the three classes, which were in turn nested within each of the three treatments. The fourth factor, acquisition and retention test scores, was a repeated-measures factor. (The pupil and class factors were treated as random factors, the other two being fixed.) The true experimental unit was classes, the observational unit being pupil test scores, following the procedure suggested by Addelman (1970). For the repeated-measures factor, the procedure suggested by Greenhouse and Geisser (1959) for determining the significance of the obtained F was used. A pooling strategy was employed in order to maximize power: alpha was set at .10 for the nested factor, hence if the null hypothesis for the difference among class means within treatments was tenable at this level, this source of variation would be pooled with the subjects within treatments and classes, thereby increasing the power for testing the main treatment effect. The results of the analysis are given in Table 3. Since this criterion was not achieved, pooling was not legitimized or employed.

Table 3

Analysis of Variance: Acquisition and Retention

Source of Variation	df	Mean Square	F
Treatment	2	21.65	1.31
Classes within treatment	6	16.47	1.96*
Students with treatment and classes	126	8.39	
Tests[a]	1	.00	
Treatment X test	2	.02	
Tests X classes within treatment	6	2.24	1.47
Tests X students within treatment and classes	126	1.52	

[a]Since residual gain scores served as dependent variables, a mean square value of .00 will always result. The hypotheses involving interactions with tests, however, are meaningful.

*$p < .10$

As shown in Table 3, there were no significant differences among the three treatment groups for acquisition or retention ($F = 1.31$) and between acquisition and retention ($F<1.0$), nor any significant interactions. There was a significant difference among the classes nested within treatments ($F = 1.96$, $p <.10$), suggesting that class means differed significantly even within the treatme . Because the main interest of this study was with acquisition and retention of multiplication facts under three different delay of knowledge of results conditions, no further attention was directed toward the classroom effect and corresponding interactions involving this effect.

Learning Patterns

A second four factor mixed model analysis of variance was performed to examine the learning patterns across the five treatment days. Pupils and classes were nested within treatments in the same manner as in the previous analysis. Days were treated as a repeated-measures factor. The dependent variable for this analysis was the difference between the number of novel problems answered correctly on both presentations of the problem for each day and the number predicted using the total pretest score as the predictor. The results of the analysis of variance are included in Table 4.

Table 4

Analysis of Variance: Daily Learning Patterns

Source of Variation	df	Mean Square	F
Treatment	2	496.89	4.46
Classes within treatment	6	111.31	5.45*
Subjects within treatments and classes	126	20.42	
Days[a]	4	.00	
Treatment X days	8	3.44	.90
Days X classes within treatments	24	3.83	1.47*
Days X subjects within treatments and classes	504	2.60	

[a]Since residual gain scores served as dependent variables, a mean square value of .00 will always result. The hypothesis involving interaction with days, however, are meaningful.

$^{*}p < .10$

The results from this analysis are similar to those reported earlier for acquisition and retention, with the only significant results involving classes nested within treatments. Treatment means did not differ significantly.

Non-novel Facts

The data collected were amenable to investigating possible effects produced by the three treatments on performance on the non-novel (and hence not taught) multiplication facts. The difference between the number of non-novel problems answered correctly on the second administration of the multiplication test and the number predicted using total pretest score as the predictor was defined as the short term effect; the difference between the number of non-novel problems answered correctly on the third administration of the test and the number using total pretest score as predictor was defined as the long term effect. These effects were analyzed using the same analysis procedure as for acquisition and retention. The results of this analysis are reported in Table 5.

Table 5

Analysis of Variance: Short and Long Term Effects

Source of Variation	df	Mean Square	F
Treatment	2	232.78	1.82
Classes within treatment	6	128.18	1.95*
Subjects within classes and treatment	126	65.76	
Length of effect (LOE)[a]	1	.00	
Treatment X LOE	2	2.36	.70
LOE X classes within treatment	6	33.78	2.09*
LOE X subjects within treatments and class	126	16.16	

[a]Since residual gain scores served as dependent variables, a mean square value of .00 will always result The hypothesis involving interactions with length of effect, however, are meaningful.

* $p < .10$

As shown in Table 5, the only significant results obtained are for classes nested within treatments and for the interaction between classes within treatment and length of effect.

Discussion

The study was designed to investigate the effect of delay of knowledge of results on the acquisition and retention of novel multiplication facts presented in a classroom situation. The findings obtained failed to support the generalization that where knowledge of results is given to one group, either immediately or delayed, and withheld from a second, comparable group, the former will reach a higher level of proficiency. The analysis previously reported indicated that the differences in the means among treatment groups were not significant. The apparent lack in differences among the three treatments was likely due to the extreme difficulty of the task for the third grade pupils. The mean scores for all groups were about 12-13 percent of the 14 novel problems for both the acquisition and retention tests. Failure to achieve higher scores was attributed to the short treatment period which leaves unanswered the question of whether or not any advantage would be gained by (1) repeating the treatments over a longer period of time, and (2) increasing the number of presentations of each problem at one time.

The three treatments utilized in the study involved differences in intertrial intervals as well as differences in delay intervals. It may well be that the results obtained were more a function of the intertrial interval than of the delay interval. Further study is needed to determine the effect of intervening material during the response interval, as was the case for the delayed group. Would a differential effect be observed if the delayed treatment involved a delay of eight seconds after the response interval, with no intervening material? In such an experiment, would the results be confounded with possible covert practice?

The significant classroom effect, a nuisance variable which has historically been implicitly pooled by investigators unfamiliar with statistical nesting, points out clearly how this source of variation can affect scores. Had this factor been ignored in the present study, the treatment results would have been erroneously judged to be statistically significant. Ideally, each treatment should be administered in each classroom to randomly selected subgroups, thus having classroom as a crossed, rather than as a nested, factor.

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Appendix A: Descriptive Data

Table 6

Means and Standard Deviations: IQ[a]

Treatment Class	$\overline{X}$	S
I. Immediate Knowledge of Results		
1	114.73	11.28
2	106.73	15.82
3	111.00	6.72
II. Delayed Knowledge of Results		
4	106.87	14.32
5	109.27	10.73
6	105.93	12.38
III. No Knowledge of Results		
7	110.33	14.44
8	104.20	12.16
9	104.67	16.30

[a]California Short-Form Test of Mental Maturity, Form 1H.

Table 7

Means and Standard Deviations: Age[a]

Treatment Class	$\overline{X}$	S
I. Immediate Knowledge of Results		
1	106.53	4.19
2	106.93	6.03
3	107.87	3.38
II. Delayed Knowledge of Results		
4	108.73	2.19
5	107.40	8.48
6	107.40	5.05
III. No Knowledge of Results		
7	106.53	5.40
8	110.33	6.99
9	107.53	2.85

[a]Age in months as of June 1.

Table 8

Means and Standard Deviations: Pretest

Treatment Class	$\overline{X}$	X
I. Immediate Knowledge of Results		
1	18.40	7.18
2	29.93	10.83
3	33.13	11.25
II. Delayed Knowledge of Results		
4	33.60	12.36
5	31.00	7.34
6	27.60	8.51
III. No Knowledge of Results		
7	31.87	15.32
8	18.27	10.33
9	24.87	9.57

Table 9

Means and Standard Deviations: Novel Problems on Acquisition and Retention Tests

Treatment Class	Acquisition $\bar{X}$	Acquisition S	Retention $\bar{X}$	Retention S
I. Immediate Knowledge of Results				
1	1.80	1.97	1.67	2.36
2	2.80	2.96	3.07	2.63
3	2.00	2.56	2.40	3.00
II. Delayed Knowledge of Results				
4	1.33	1.40	2.80	4.51
5	2.33	2.72	2.27	3.24
6	1.33	2.69	1.00	1.93
III. No Knowledge of Results				
7	3.00	3.93	3.53	3.96
8	.13	.35	.20	.56
9	.73	1.62	.40	.74

Table 10

Means and Standard Deviations: Non-novel Problems on Acquisition and Retention Tests

Treatment Class	Acquisition $\bar{X}$	Acquisition S	Retention $\bar{X}$	Retention S
I. Immediate Knowledge of Results				
1	20.53	9.12	21.67	8.19
2	30.33	11.57	33.80	12.60
3	36.07	10.16	37.87	10.23
II. Delayed Knowledge of Results				
4	31.87	12.14	31.33	12.66
5	30.87	7.86	33.53	8.73
6	29.87	10.88	31.07	12.42
III. No Knowledge of Results				
7	29.00	16.68	27.07	17.08
8	18.40	11.98	20.40	12.38
9	24.60	12.34	28.67	11.01

Table 11

Means and Standard Deviations: Novel Problems on Treatment Days

Treatment Class	Day 1		Day 2		Day 3		Day 4		Day 5	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
I. Immediate Knowledge of Results										
1	5.13[a]	4.31	5.40	3.94	5.67	4.05	5.33	4.10	5.47	3.90
2.	2.47	2.17	2.67	2.16	2.73	2.55	3.27	2.22	4.07	2.34
3	5.00	4.23	2.60	2.23	2.47	2.26	2.47	3.34	3.33	3.74
II. Delayed Knowledge of Results										
4	2.20	2.40	1.53	1.85	1.07	1.10	2.80	4.49	3.00	4.63
5	1.07	1.75	.53	.92	.87	1.60	1.53	2.33	1.33	1.84
6	1.27	1.83	.73	1.44	.80	1.78	1.13	1.96	1.27	2.15
III. No Knowledge of Results										
7	2.46	3.27	2.13	3.60	2.93	3.53	3.27	4.03	3.20	4.20
8	.13	.35	.07	.26	.53	.92	.53	.99	1.07	2.19
9	.40	.63	.20	.56	.60	1.30	1.33	1.59	1.00	1.25

[a] A problem was considered correct only if it was answered correctly on both presentations of the problem.